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James F. MacLaren Ltd.

REPORT TO ONTARIO HYDRO ON ASSESSMENT
OF THE EFFECTS OF SHORELINE DISCHARGE
ALONG THE EXPOSED SHORE OF THE GREAT
LAKES 1979.

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CONSULTING ENGINEERS, PLANNERS AND SCIENTISTS

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REPORT
TO ONTARIO HYDRO
ON
ASSESSMENT OF THE EFFECTS OF
SHORELINE THERMAL DISCHARGE
THE GREAT LAKES

BY

JAMES F. MacLAREN LIMITED

November 1979

ASSESSMENT OF THE EFFECTS OF
WINDMILL THERMAL POLLUTION
ALONG THE SHORELINE OF
THE GREAT LAKES

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the generous support I have received from the two ministries and Ontario Hydro in gaining the background information on which this report is based. In particular, I must acknowledge the help received from Messrs. Christie, Effer, Faisst and Jenkner of Ontario Hydro; D.P. Dodge and many other members of the Fisheries Branch of the Ministry of Natural Resources; and L.F. Moore of the Water Resources Branch of the Ministry of the Environment.

Dr. F.E.J. Fry

ASSESSMENT OF THE EFFECTS OF
SHORELINE THERMAL DISCHARGE
ALONG THE EXPOSED SHORE OF
THE GREAT LAKES

With special reference to the proposed
Darlington Nuclear Generating Station

1.0 INTRODUCTION

This report must be opened with an apology for its baldness. It presents merely a few general principles distilled from what is now a wealth of research and cannot do justice to all the workers so active now in making their contributions to these problems nor to the agencies which are supporting them. The research referred to is that aimed at the mitigation of the impact our economic and indeed also recreational activities now exert so forcefully on our environment.

Three agencies in Ontario in particular are thus active: the Ontario Ministries of Environment and Natural Resources and Ontario Hydro. Each of these agencies has senior personnel who understand the problems and capable young people who are making effective use of the support their seniors provide. This is not to say Utopia has been reached. Realization of the problems we are faced with is no more than a generation old, nor indeed are the problems themselves along the Canadian shores of the Great Lakes. Concerted action to face these environmental issues goes back only half that time when the need to shift from exploitative to benign engineering first began to be apparent. In consequence, events still overwhelm us to a great degree. This report is a consideration of one small facet of such responsibilities. It addresses itself only to the mitigation of the problems we anticipate from the discharge of cooling waters from one of the new generation of electrical power generating stations, namely the proposed Darlington Nuclear Generating Station on the north shore of Lake Ontario.

2.0

THE INSHORE HABITAT OF THE GREAT LAKES

The littoral zone is ordinarily defined as the marginal area of a lake down to the depth where photosynthesis is extinguished. Thus defined, it limits the area where submersed rooted aquatic plants can exist. The presence of such macrophytes provides for increased cover and surface and enhances the habitat, particularly for smaller organisms which are the basis of productivity. However, the littoral zone is by no means a uniform habitat and is greatly modified by the degree of exposure of the shoreline at any particular site. In particular, in freshwaters, strong wave action on shores exposed to a long fetch of the wind will lead to a dearth of macrophytes, either because the bottom is bedrock* or because any sediments will be kept unstable.

These exposed sections of the Great Lakes shoreline, which following Barton and Hynes (1978a and elsewhere) will be termed here the wave zone, have received little attention from biologists until the recent publications of the authors cited above (see also Barton and Hynes, 1978b and c). The quiet littoral with its abundant cover and fixed vegetation which can capture the nutrients of the primary runoff is the most productive habitat of the lake ecosystem. In contrast, the wave zone in the Great Lakes can be an exceedingly inhospitable habitat, particularly along those sections where the substrate is unstable sediment. In addition to the mechanical effects of wave action, summer water temperatures on exposed shores of the Great Lakes are unstable (Figure 2). Such temperature fluctuations are most extreme on the exposed shores but occur also in more sheltered locations although not to the same degree.

* The beds of seaweeds characteristic of rocky seacosts are represented in inland waters only by a few filamentous algae such as Cladophora.

FIGURE 1: Schematic profiles of the inshore zone.

- A: Wave Zone
- B: Sheltered Littoral

The beds of seaweeds characteristic of rocky coasts are represented in inland waters only by a few filamentous algae such as *Cladophora*.

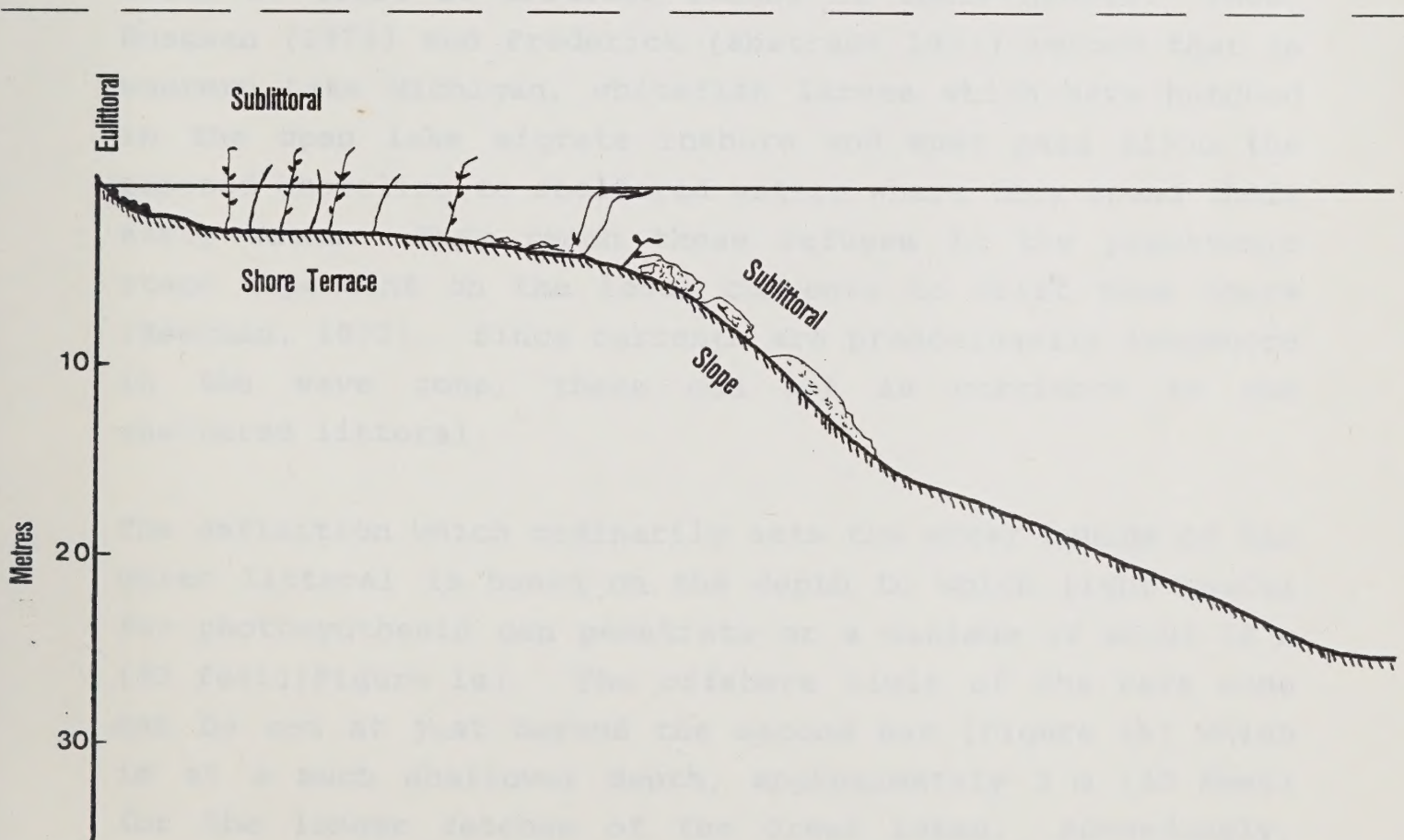
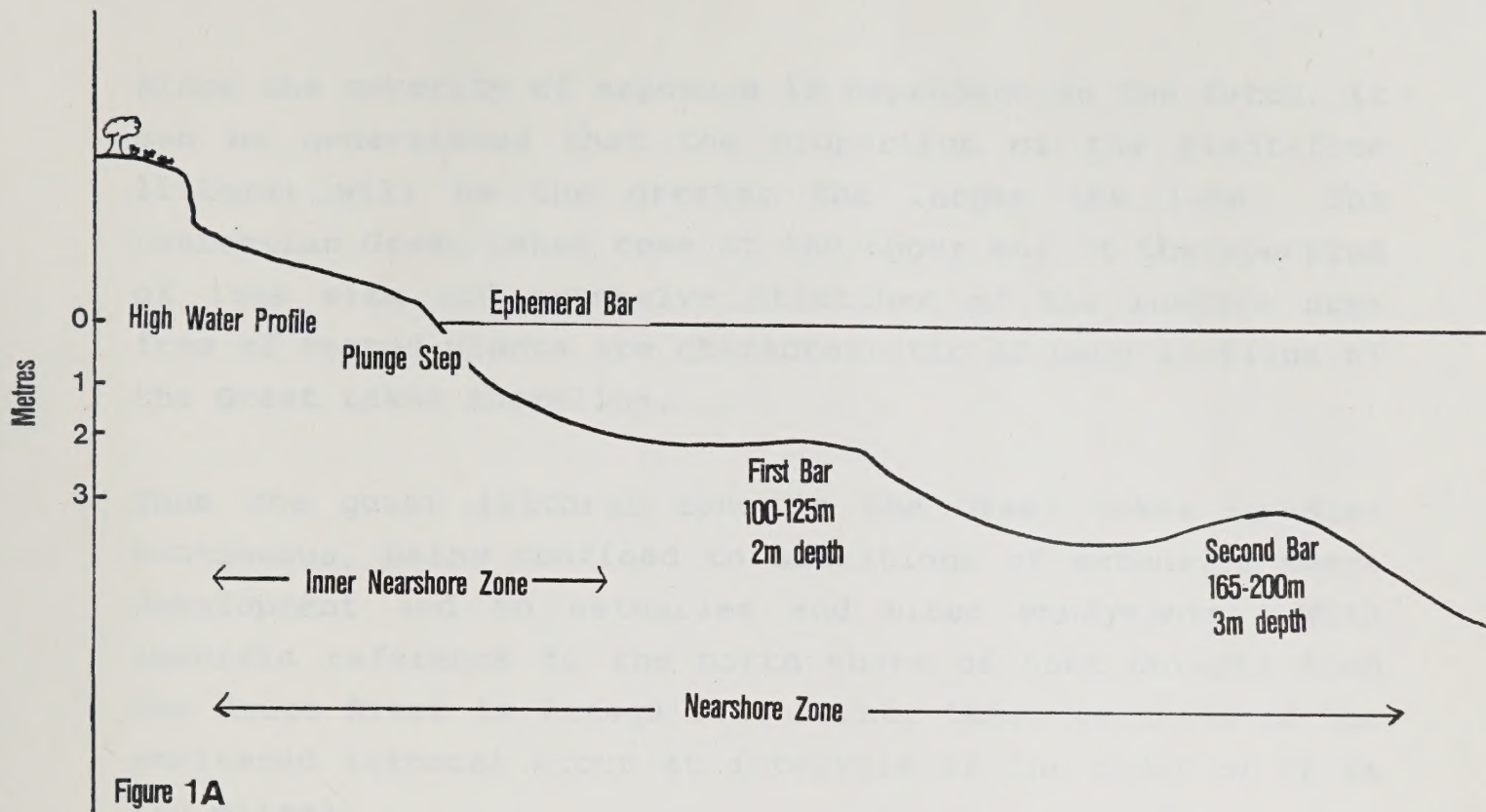


Figure 1B

Since the severity of exposure is dependent on the fetch, it can be generalized that the proportion of the plant-free littoral will be the greater the larger the lake. The Laurentian Great Lakes come at the upper end of the spectrum of lake size and extensive stretches of the inshore area free of rooted plants are characteristic of many sections of the Great Lakes shoreline.

Thus the quiet littoral zone in the Great Lakes is discontinuous, being confined to situations of extensive shore development and to estuaries and minor embayments. With specific reference to the north shore of Lake Ontario from the Rouge River to Presqu'isle Point, these sections of the sheltered littoral occur at intervals of the order of 16 km (10 miles).

Reproduction of many species is favoured by these sheltered areas at least at critical stages of their growth. Thus, Hoagman (1973) and Frederick (abstract 1977) record that in western Lake Michigan, whitefish larvae which have hatched in the open lake migrate inshore and must pass along the exposed shoreline to sheltered waters where they spend their early weeks. They reach these refuges in the planktonic stage dependent on the local currents to drift them there (Hoagman, 1973). Since currents are predominantly longshore in the wave zone, these can act as corridors to the sheltered littoral.

The definition which ordinarily sets the outer bounds of the quiet littoral is based on the depth to which light useful for photosynthesis can penetrate or a maximum of about 10 m (33 feet)(Figure 1a). The offshore limit of the wave zone can be set at just beyond the second bar (Figure 1b) which is at a much shallower depth, approximately 3 m (10 feet) for the longer fetches of the Great Lakes. Accordingly, different limits can be set for the limits beyond which undesirable discharges should not impinge on these two segments of the inshore habitat.

In particular, social development has already led to such reduction of the quiet littoral in the lower Great Lakes through harbour development and the filling in of wetlands that such areas as are still left require jealous conservation. In consequence the offshore depth limits of any consequential impingement should be at least the conventional 10 metres and probably more. However, the ecological function of the wave zone as an access route to the quiet littoral, while equally important, does not appear to need as broad an offshore reservation to maintain its function.

FIGURE 2: Inshore temperature record off the Darlington Site. The envelope labelled maximum temperature indicates the generalized surface temperature. Departures from it represent upwellings. Conditions below the maximum -5° contour represent times when the thermal discharge after initial mixing will enter the lake at a temperature below the prevailing equilibrium temperature and will contribute to deepening the hypolimnion.

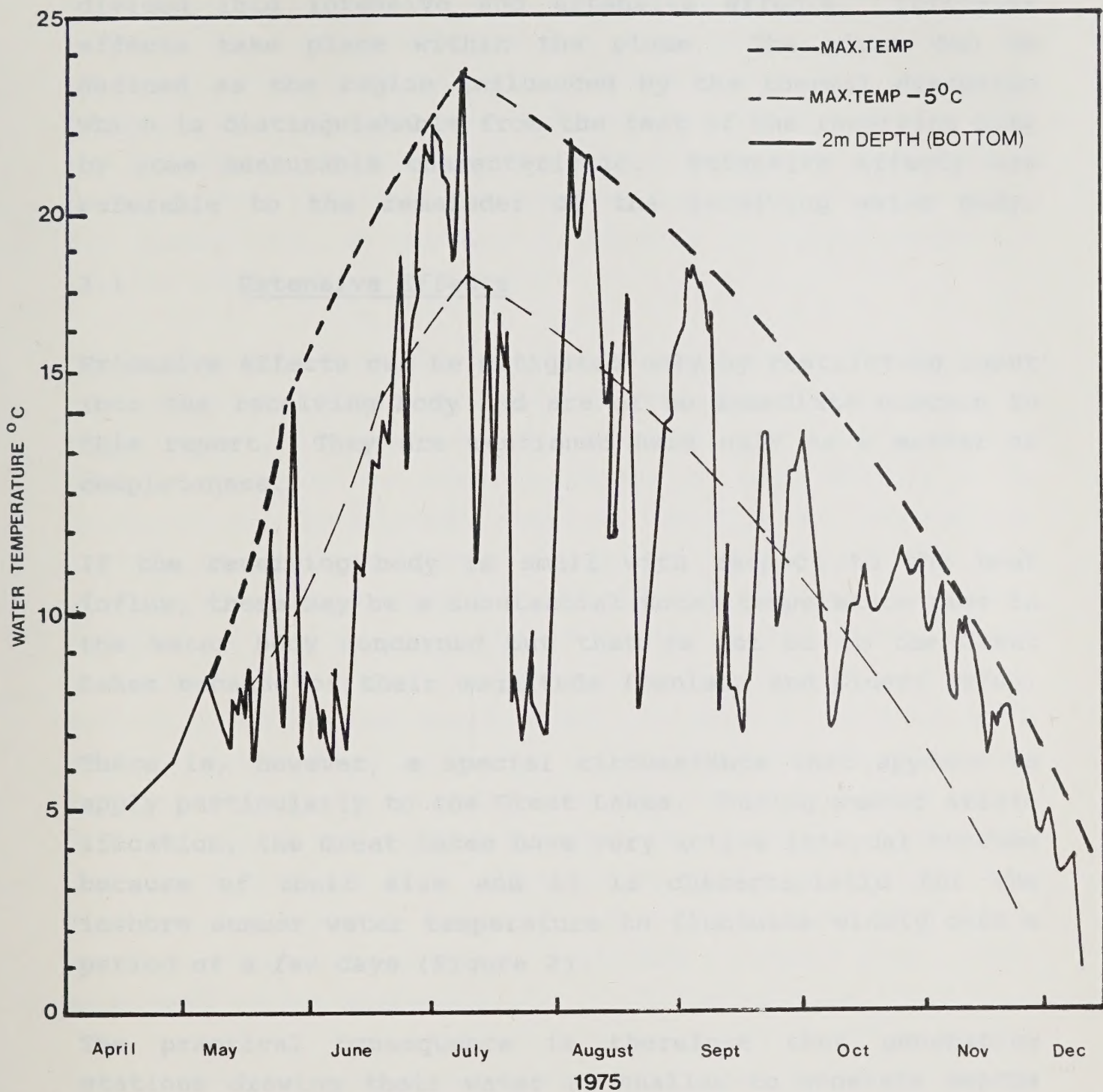


FIGURE 2

3.0 EFFECTS OF HEATED EFFLUENTS ON FISH

The ecological effects of heated effluents are conveniently divided into intensive and extensive effects. Intensive effects take place within the plume. The plume can be defined as the region influenced by the thermal discharge which is distinguishable from the rest of the receiving body by some measurable characteristic. Extensive effects are referable to the remainder of the receiving water body.

3.1 Extensive Effects

Extensive effects can be mitigated only by restricting input into the receiving body and are of no immediate concern to this report. They are mentioned here only as a matter of completeness.

If the receiving body is small with respect to the heat influx, there may be a substantial total temperature rise in the water body concerned but that is not so in the Great Lakes because of their magnitude (Denison and Elder, 1970).

There is, however, a special circumstance that appears to apply particularly to the Great Lakes. During summer stratification, the Great Lakes have very active internal seiches because of their size and it is characteristic for the inshore summer water temperature to fluctuate widely over a period of a few days (Figure 2).

The practical consequence is therefore that generating stations drawing their water at shallow to moderate depths nevertheless tap the hypolimnion at least a quarter of the summer period (Yaguchi, 1977 and Figure 2). Water so drawn from the hypolimnion is heated largely to epilimnial temperatures and on its return contributes to extending the epilimnion. The effect however is not great. A rough calculation suggests the Darlington discharge will deepen the epilimnion by a few centimetres. Perhaps more important is the retention of the upwelled water in the trophogenic zone.

3.2 Intensive Effects along Exposed Shores

Intensive effects may be thermal, chemical or mechanical and will differ in their operation as to whether the organisms subject to their influence are sedentary, planktonic or capable of effective independent locomotion. With regard to fish in general, eggs are sedentary in freshwater, larvae are planktonic and fish are capable of effective independent movement from the juvenile stage onward. At all stages they are susceptible in one way or another to the effects of thermal effluents.

Adult fish have a marked behavioural response to differences in temperature. They gravitate toward a particular range of temperature characteristic of the species at a given season and in relation to their previous thermal history. In general, the behavioural response of fish to temperature leads them to temperatures favourable to their growth and activity, although there are notable exceptions. A local example is the observations of Graham (1956) who recorded the death of alewives in the spring as they entered water naturally warmed over shoal water. Everest (1972) reports a similar instance of mortality apparently occasioned by the Hearn effluent. Thus, there are circumstances under which fish disregard temperature gradients to their own detriment. The converse "will they disregard to their advantage?" has not been so clearly analyzed and the fear has often been expressed that attraction to a thermal effluent will interfere with normal migration.

When effluents have been confined to extensive channels or discharged into enclosed water bodies such as harbours, there are cases of winter-long congregations that have led to fish being in poor condition or to death by chilling when the plant has been shut down, but by and large when effluents have been discharged along the open shore lines there is no indication of great interference with the normal

patterns of migration, either offshore, onshore or along the shore. There are, it is true, concentrations of salmonids in winter around thermal effluents (Spigarelli and Thommes, 1976) that indeed are taken advantage of by anglers, but there seems to be no indication that these interfere with spawning migrations.

Work on fish residence in thermal plumes has received great impetus with the development of radio-tags. In these investigations, Ontario Hydro is making substantial contributions (Minor, 1978, 1979). In particular, smallmouth bass and white bass resident in the vicinity of the cooling water outfalls of the Hearn and Pickering generating stations have been tagged and their movements followed by radio-telemetry for periods of up to two months. Over most of these observations the smallmouth bass and white bass were clearly primarily resident at points determined by the plumes. But in the Hearn effluent as summer progressed the white bass had increasingly greater absences from the plume until in September they were gone. Such observations are in general concordance with the seasonal differences in entrainment shown by the various species. For example, the seasonal occurrence of alewives in the Pickering forebay corresponds to the normal onshore occurrence of the species elsewhere in the Great Lakes, although on occasion alewives do frequent the thermal effluent.

Where species are resident in an effluent this is not necessarily to say that the effluent is a thermal trap which will draw the species concerned to destruction. Rather, it may indicate a favourable site for as large a population as can exploit it. A year-long study of Parr Pond (Quinn et al., 1978), a long, branching, reservoir of 1,120 ha. (453 ac.) with a power plant on one arm, showed all arms had resident populations of largemouth bass which homed to their own areas and mixed only to a slight degree. The mixing demonstrated that they could come in contact with the thermal effluent but the remainder of the reservoir remained adequately colonized.

FIGURE 3: Estimates of the 20 cm/sec surface current speed contour for a model plume for the proposed Darlington A generating station.

Design identical to proposed outfall ■
adjusted model results from designs under
that proposed for this site●. Data from
the Hydraulic Model Laboratory, Ontario
Hydro.

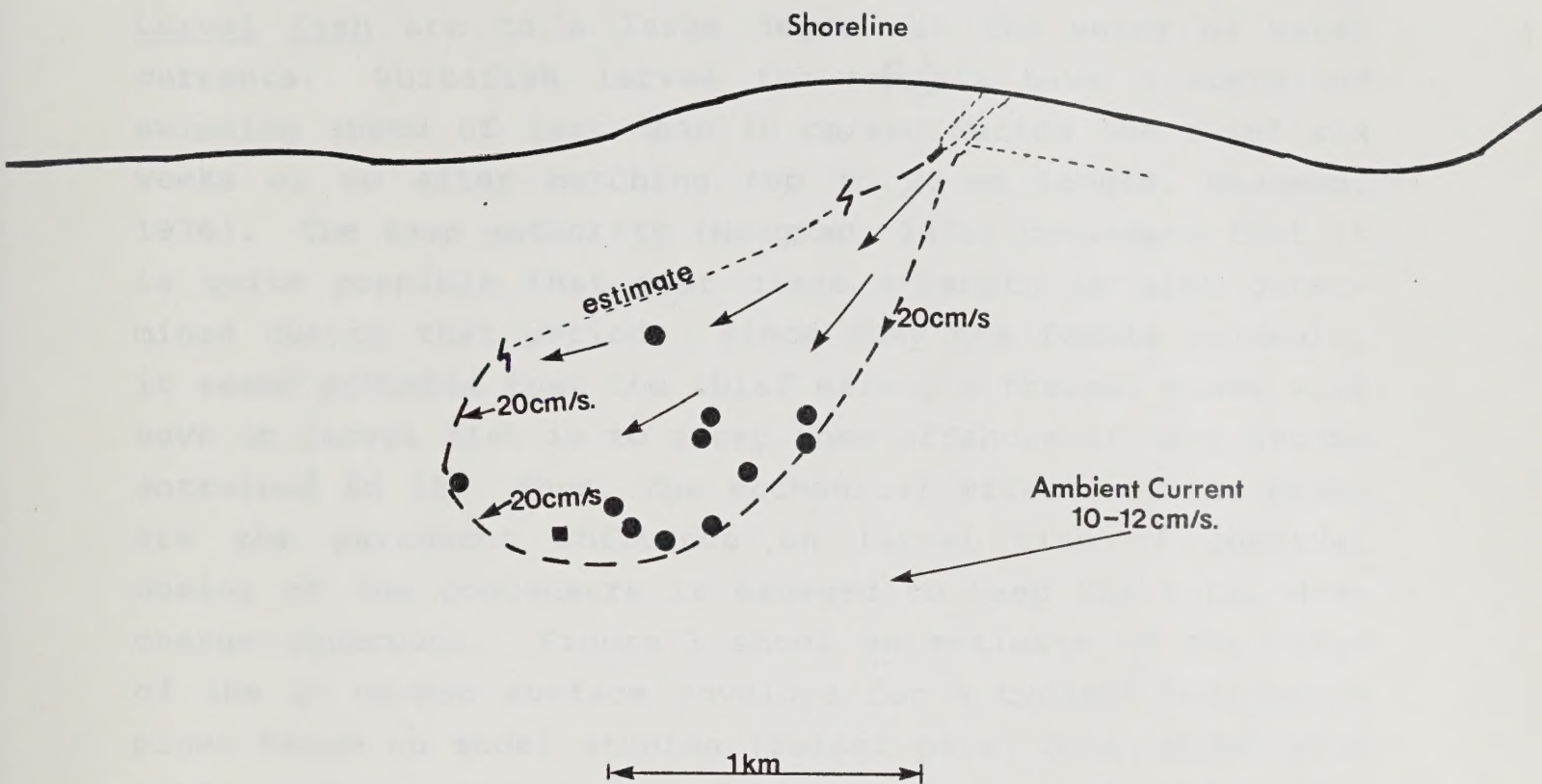


FIGURE 3

The general conclusion is that thermal effluents discharged directly into an open body of water have little detrimental effect on adult fish. This conclusion is supported by a recent extensive review (Utility Water Act Group, 1978).

Larval fish are to a large degree at the mercy of water currents. Whitefish larvae for example have a sustained swimming speed of less than 10 cm/sec during the first six weeks or so after hatching (up to 20 mm length, Hoagman, 1974). The same authority (Hoagman, 1973) considers that it is quite possible that year class strength is also determined during that period. Since they are feeble swimmers, it seems probable that the chief effect a thermal plume will have on larval fish is to sweep them offshore if they become entrained in it. Thus, the mechanical effects of the plume are the paramount influence on larval fish if chemical dosing of the condensers is managed to keep the total discharge innocuous. Figure 3 shows an estimate of the range of the 20 cm/sec surface envelope for a typical Darlington plume based on model studies (Faisst pers. comm. model with 1000' groins). The projected length of the surface envelope is about 2 km. As Figure 4 indicates, the depth of the 20 cm/sec stratum is about 2 m. at one km. Based on the data in the figures above, Figure 5 shows an estimate of the order of magnitude of the diversion that would be suffered by a drifting larval fish if entrained in an onshore, surface plume. Thus, a thermal plume discharging directly into the wave zone can operate as a large rip current to divert offshore larvae that would otherwise drift to the nearest protected littoral in the longshore current.

Fish eggs in freshwater are ordinarily buried in the substrate or attached to it. Thermal plumes in our climate have the greatest impact on the bottom during the winter when ambient water temperatures are below the temperature of maximum density. Under those circumstances the plume cools to about 4°C and although still warmer than the surrounding water sinks below it (Sato and Mortimer, 1975). Besides

FIGURE 4: Estimated typical velocity profile
of a floating plume at Darlington A
G.S. Data from the Hydraulic Model
Laboratory, Ontario Hydro.

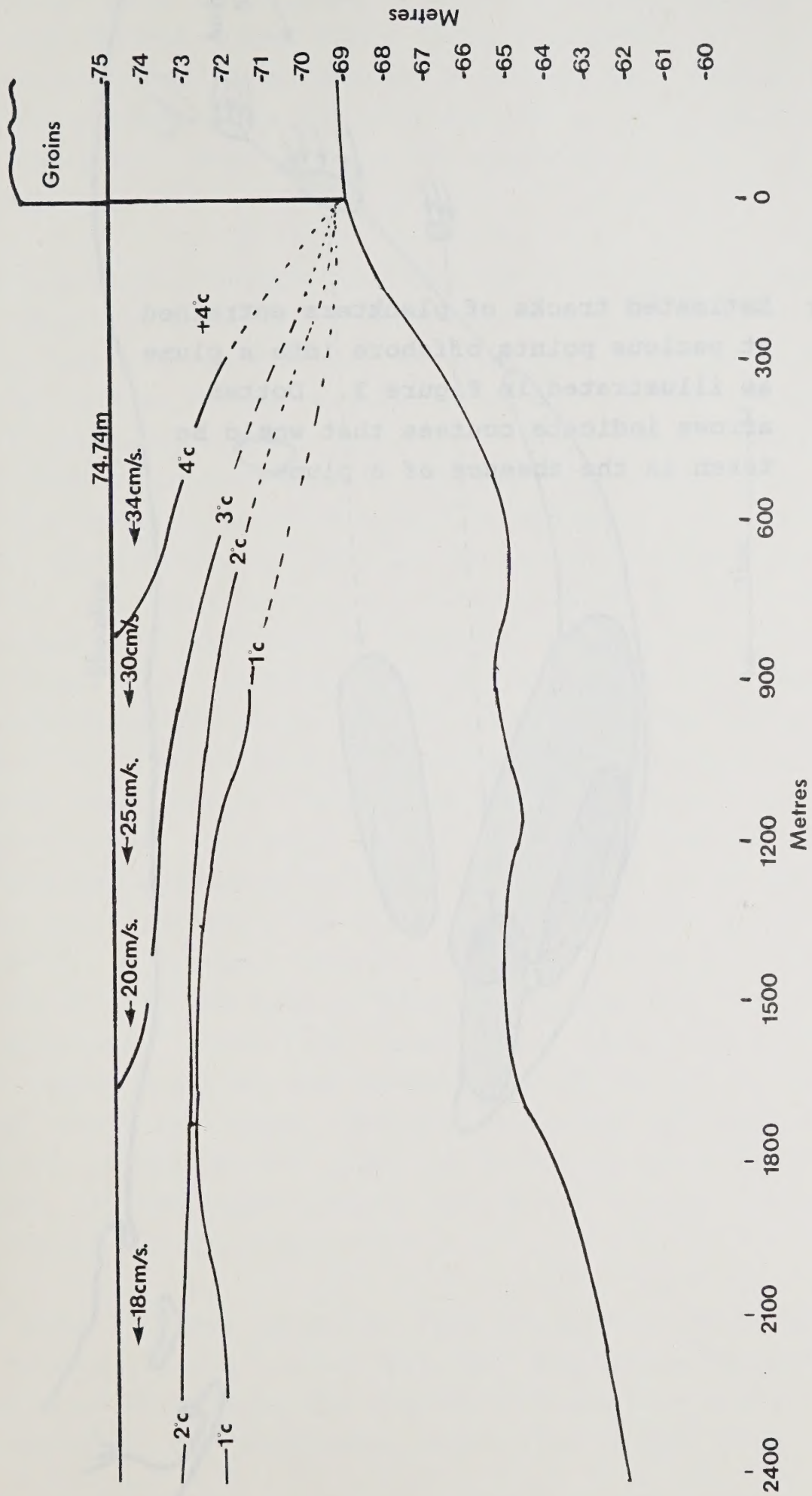


FIGURE 4

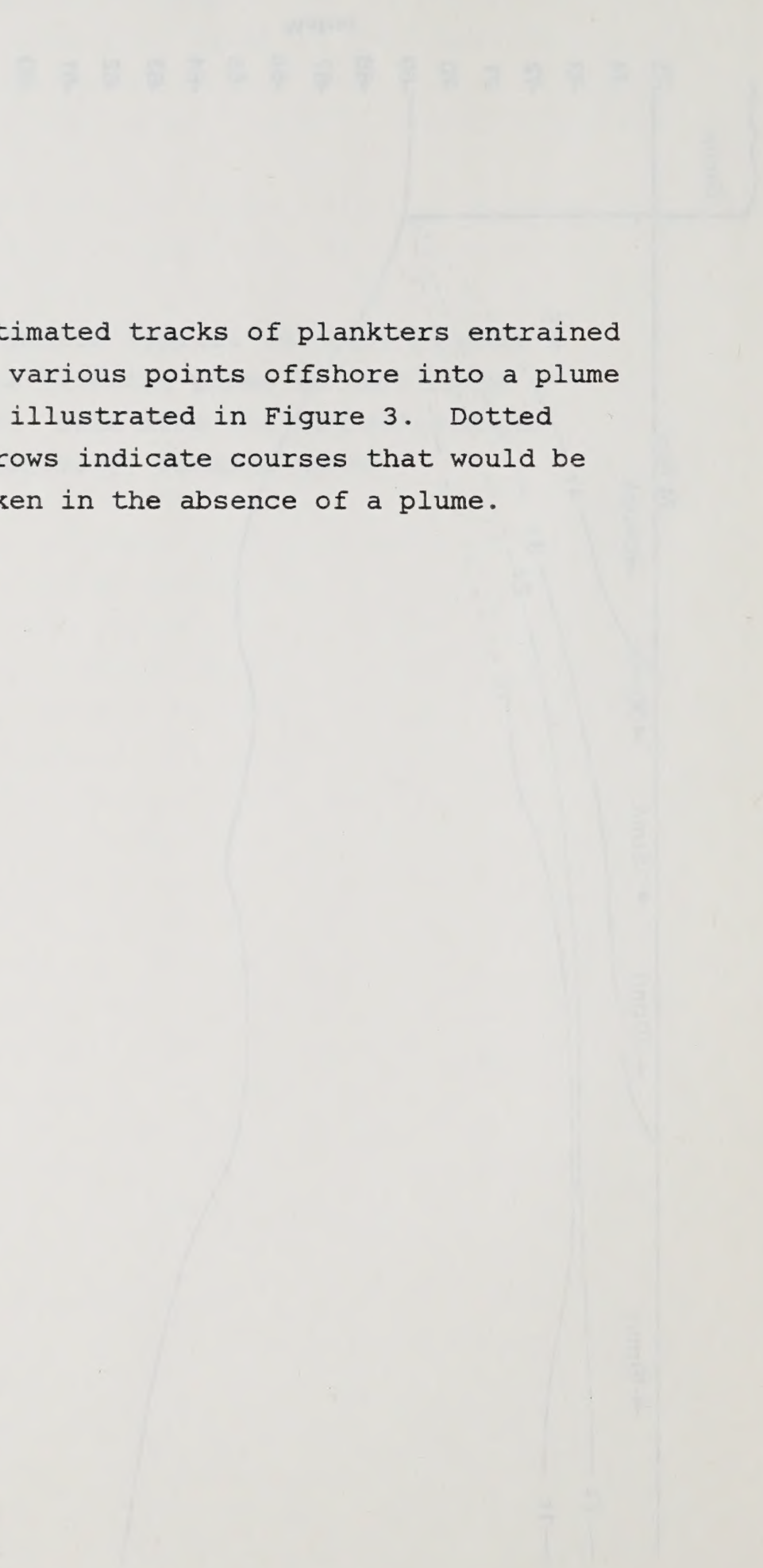


FIGURE 5: Estimated tracks of plankters entrained at various points offshore into a plume as illustrated in Figure 3. Dotted arrows indicate courses that would be taken in the absence of a plume.

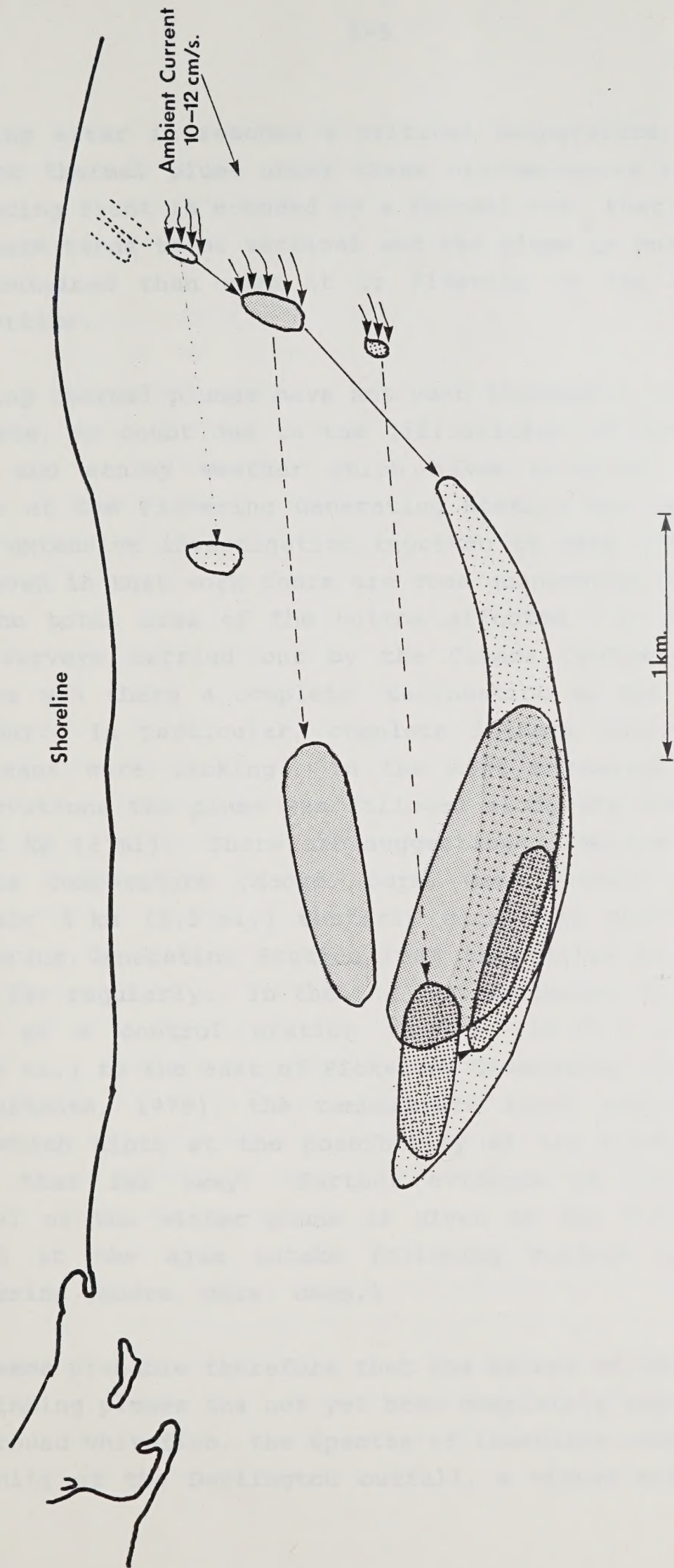


FIGURE 5

sinking after it reaches a critical temperature, a feature of the thermal plume under these circumstances is that its advancing front is bounded by a thermal bar, that is the 4°C isotherm tends to be vertical and the plume is more compactly contained than when it is floating on the surface in summertime.

Sinking thermal plumes have not been thoroughly investigated to date, no doubt due to the difficulties of field work in cold and stormy weather which makes progress slow. The plume at the Pickering Generating Station has received the most extensive investigation reported to date (Arajs, 1978) but even in that work there are some unanswered questions as to the total area of the bottom affected. In none of the ten surveys carried out by the Canada Centre for Inland Waters was there a complete delineation of the 4°C bottom contour. In particular, complete inshore observations to the east were lacking. In the most extensive series of observations the plume was followed along the eastern shore for 3 km (2 mi). There are suggestions from the Ajax water intake temperature (Moore, pers. comm.) which is approximately 4 km (2.5 mi.) easterly along the shore from the Pickering Generating Station that the winter plume reaches that far regularly. In the one January record (1977) available at a control station in 6 m (19 ft.) depth, 6 km (3.75 mi.) to the east of Pickering Generating Station (Beak Consultants, 1979), the temperature rises episodically to 5°C which hints at the possibility of the plume influence even that far away. Further evidence of the longshore travel of the winter plume is given by the tritium values found at the Ajax intake following various releases at Pickering (Moore, pers. comm.).

It seems probable therefore that the extent of the influence of sinking plumes has not yet been completely assessed. For the round whitefish, the species of immediate concern in the vicinity of the Darlington outfall, a winter mean tempera-

ture of 4°C as opposed to 2°C would result in hatching about one month prematurely (Figure 5.5 in Maher, 1978). The crucial question therefore is what will realistically be the area of influence of the sinking plume.

After hatching, the fry on rising from the spawning bed must take a trip to the water surface to fill the swim bladder with its first air bubble. Should the plume be over the bed at this time, they are then immediately subjected to whatever is its current speed at that point. That current will normally tend offshore and will add its bias to the normal probability of an unfavourable current at that crucial time.

3.3 Summary of Effects

In summary, except for the chemical hazard which can be managed, conventional onshore thermal discharges into open surface water appear to offer little hazard to adult fish. They appear, however, to be a dynamic barrier to longshore larval drift and could interrupt the migration of the larvae from offshore spawning beds which depend^s on an unimpeded wave zone to reach the protected littoral. With respect to the first rise of larvae from an offshore spawning bed which may come under the influence of the thermal plume, a similar effect of the plume current may disperse them offshore. Spawning beds in which the eggs develop over winter may be adversely affected by the winter plume. Assessment of the area which will come under the influence of the sinking plume is not yet complete.

Of these various effects, the interruption of the longshore drift seems to be the most universal and greatest hazard of onshore cooling discharges in the Great Lakes, given the historic value of the whitefish and the lake herring fisheries. The effect of the sinking plume is a local problem of as yet unassessed dimensions, as is otherwise the effect

of the plume passing over a local spawning bed at the time the fry are rising. Effects on the biota other than the direct effect on fish have not been discussed since it is considered that these in general are more limited.

3.4 Remedial Considerations

The conclusion does appear inescapable that any discharge of cooling water along the exposed shoreline of the Great Lakes should not interfere with the normal longshore currents which, where there are movable sediments, are inshore of the second bar, or otherwise presumably within the breaker zone. Thus, the width of this zone along an unimpeded shoreline is of the order of 200 m. The question is then what would be an adequate gap to be left between any works and the shoreline to leave this longshore current unaffected. That question cannot be answered within the competence of the present report since all the local variables would need to be assessed, in particular whether the disposition of local shore modifications or entrainment of shore water into the discharge itself would favour the generation of rip currents.

It is considered that local onshore increases of temperature due to impingement of the plume are not likely to be of biological significance in the wave zone. That habitat is an unstable one for most species. Thus, the offshore distance of any discharge on an open shore need not be determined on a temperature basis.

While the question of separation of the point of discharge from the shoreline is a general one, any significant impingement of the winter plume on spawning beds is a local consideration. With respect to the Darlington site there does not seem to yet be sufficient data to provide a definitive solution. There is no doubt a spawning shoal frequented by

the menominee that can come under the influence of the Darlington plume. However, the importance of that shoal in comparison to other spawning areas of the species has not been assessed. In addition, some further assessment of the local disposition of the sinking winter plumes needs to be made. The remedy needs to be matched to the importance of the potential loss.

If the importance of the spawning is strictly local, a prudent course might be to replace it with a small local hatchery or a contribution to hatchery operations elsewhere. At the present state of the art, such a remedy is speculative but it is reasonable to anticipate progress in cultural methods. Moreover, the aim is to rehabilitate the fishery, not restore it, so that another species might be supported rather than the menominee now believed to use the reef.

If the spawning bed is of major importance, the remedy would appear to require a diffuser type discharge specifically designed to prevent the formation of a sinking plume.

It must be said, however, that we do not have the information to know how important the spawning bed is; nor does any agency appear to have the determination at the moment to enter into the minutae of such a survey.

4.0 THE FISHERIES RESOURCE OF LAKE ONTARIO WITH PARTICULAR REFERENCE TO THE DARLINGTON SITE

4.1 Commercial Fishing off Durham County

The Lake Ontario fish community is now at its lowest socio-economic value and probably also at a fraction of the biological potential which can be expected to be realized with the effort at environmental improvement and fisheries management in train or now being planned.

The history of the Lake Ontario commercial fishery was well recorded by Christie (1973) up to 1970. Further changes to 1977 are chronicled in the Lake Ontario Fisheries Background Report, Ontario Ministry of Natural Resources (1978). A century ago the lake supported stocks of Atlantic salmon, lake trout, lake whitefish and other coregonines in the open waters of the main lake, while the more sheltered areas had populations of pike, maskinonge, walleye and bass. In short, all the desirable lacustrine species of our region were abundant. Over-fishing, introduction of exotic species and the impact of settlement on streamflow and shoreline have all combined to bring about undesirable changes within a century. With all the changes, however, the lake has by no means become an impossible habitat for fish and in terms of biomass is still heavily populated although by species not now desirable such as the alewife, nor easily harvested, such as the smelt, or too contaminated for habitual consumption, such as the planted coho.

To document the changes in the fishery off Durham County and present fish populations in the vicinity of the Darlington site, various tables are given in Appendix 1 for the period 1924 through 1977. Over that period, there have been great changes in the fishery, both in the total catch and particularly in the major species taken. The principal species taken over the period was the lake herring which dominated the catch from 1929 to 1951, and then has been commercially

extinct since 1956. Lake whitefish, although never as prominent in the catch as lake herring, also provided substantial yields up to 1939 and lesser amounts over the next decade after which they, too, virtually disappeared from the fishery.

In recent years, the menominee, or round whitefish, has undoubtedly been the source of most of the few whitefish taken, but it was not separately reported in the Lake Ontario records until recently. Since 1976, a few hundred pounds per year have been reported. The largest recent catch has been in 1978 for which the preliminary statistics show about 2,000 pounds taken in the fall with limited fishing. The third valuable species in the early records was the lake trout which however ceased to be a factor in the catches after 1930. Smelt first appeared in the records in 1953 at which time the catch of smelt equalled the catch of herring. Since then, they have been the principal species taken in the commercial fishery. The catch reached a peak of 115,000 pounds in 1956 and has been of the order of 30,000 pounds since then with considerable annual fluctuations. The fishery, therefore, throughout the period has been sustained by species we recognize as adapted to cold or cool waters and of the group we broadly recognize as salmonoids.

Conversely, the warm water species such as the yellow perch have never been an important factor in the fishery off Durham County.

4.2 Sport Fishery

In contrast to the commercial fishery, which has been so well documented throughout its decline, there are few statistics available for the sport fishery which promises to become more and more important. Cox and Straight (1975) estimated that in 1970, Lake Ontario and its immediate tributaries provided 1.6 million angler days of sport fish-

ing and generated some \$10 million of related expenditures. Table 7, Appendix, which summarizes some recent Lake Ontario creel census reports covering some 100,000 angler days, shows how widespread the active present angler interest is, even in spite of the widely publicized warnings that meals of Lake Ontario fish should be restricted at the present time because of the pesticide content.

With respect to the northern shore of Lake Ontario, the rainbow trout is a growing resource based on spawning runs that have been built up in many of the streams in recent years. Bowmanville Creek and the Ganaraska River both now have important runs of rainbow trout which can be expected to frequent the Durham County shoreline during their growth period in the open lake. Brown trout planted in New York State, also occur off these streams. Seeding of coho and chinook salmon planted in Ontario is at present confined to the western end of the lake. Lake trout are currently absent from the sport as well as the commercial fishery.

4.3 Test Netting off the Darlington Site

Table 3, Appendix, gives the various catches made in recent years in test gillnets of a range of mesh sizes. The data were not reduced to catch per lift and can be considered only as comparisons between species and not as between years.

The test netting took an array of species that is normal for Lake Ontario, a list that would be extended among the smaller species if the test trap net catches were also included. The two species notably absent from these inshore samples are the lake trout and the lake herring, which have also become commercially extinct in the vicinity. The planted lake trout now present in eastern Lake Ontario have not shown up off the site. The essential difference between these test catches and the commercial statistics is the predominance of alewife in the test series. Alewife are

undoubtedly the most abundant species in the vicinity. What alewife as were reported in the commercial landings are included in the category "coarse fish". However, since they have little or no commercial value locally and since they are a nuisance to gillnetters, the commercial operation in general avoids them.

A special feature of the test netting was a study of menominee spawning activity in November-December 1977 (Dunford, 1978). A simplified condensation of these data is given in Table 6, Appendix. These catches appear to show an assembly of the population to the east of Raby Head in early November with a movement to near the proposed outfall site for the actual spawning. Ripe fish were taken on December 6.

Tows for larval fish were carried out off the Darlington site in 1978 (Vascotto, 1978). Smelt were the most abundant species with alewife and slimy sculpin being also well represented. One carp was taken, two larval whitefish (as yet unidentified) were taken early in the year (Dunford, pers. comm.). The three abundant species represented by larvae are the three species which almost totally comprise the fish biomass in the open lake.

4.4 Projections for Lake Ontario Fisheries

At the present time the open waters of Lake Ontario are populated with alewife, smelt and sculpin which provide a large biomass not at present directly desirable to man. It is recognized that offshore predators are required to restore a population balance. Historically, these predators were lake trout and burbot with, further in the past, the Atlantic salmon. As a step to restoring the lake trout, lamprey control was initiated in 1972; that control is now at least partially successful. At present, substantial plantings of lake trout are being made with the expectation that a new spawning stock will be established. Such a stock

should lead to a renewed fishery off Durham County. In addition, various other salmonids, rainbow and brown trout and coho salmon, are also being planted to take further advantage of the massive stock of forage fish. On the whole, survival of these planted stocks is good and their exploitation by the sports fishery is popular. These various plantings totalled some 2.5 million yearlings and fingerlings in 1977 and about 2.2 million in 1978 (Kolenosky and Jollif, 1979).

There has been speculation that the high populations of alewife and smelt may have been inimical to the reproduction of the coregonines and indeed also of the lake trout. Thus, if the top predators can be established to control the smelt and alewife, there is a hope, although a speculative one, that lake herring and whitefish populations may also improve. There may be some significance in the dyschrony displayed by the lake herring and the whitefish fishery off Durham County (Christie, 1973 and later statistics). The whitefish fishery followed the general trend of the eastern Lake Ontario fishery but the lake herring showed an upswing at the time when the eastern catch was down which strongly suggests at least one spawning site to the west. Thus, there may be spawning beds along the mid-northern shore with potential for lake herring.

There is also some suggestion of a focus for whitefish reproduction probably to the west of Ontario County. The whitefish fishery off Ontario County (Table 5) was on the whole better off than Durham County in recent years and persisted still better in the most western statistical district 1 although the record is clouded by the lack of separate reporting for menominee.

At the same time as lamprey control has been pursued, control of phosphorus inputs into the lake is being carried out under the terms of the Canada-U.S. water quality agree-

ment. There has already been substantial reduction in loadings which should lead to substantial improvement in the inshore habitat, other conditions remaining equal. In particular, the upsurge in Cladophora may have been related to increased phosphorus loadings. Cladophora now characteristically covers the rubble of former salmonoid spawning sites and may have been a factor in the loss of these species.

In consequence, with the activities outlined above, together with other progress in pollution control also being achieved, we can look on the present state of the Lake Ontario fishery as being a point where it is poised to recover from an all-time low, not as being in a continuous decline. This prospect of recovery is not a random event but is a determined social process towards which a major economic effort is being put forward. The Lake Ontario fishery cannot be written off. Moreover with the threat of acidification of our southern Precambrian lakes now the prime site for local and tourist recreation, the need for attractive fisheries in our major accessible well-buffered waters will become increasingly more pressing. Lake Ontario is one of these major waters.

REFERENCES

Arajs, A.A. 1978. An analysis of cold weather thermal plumes. Ontario Hydro, Hydraulic Studies Dept. Rept. No. 78083: No pagination.

Barton, D.R. and H.B. Hynes. 1978a. Wave-zone macrobenthos of the exposed Canadian shores of the St. Lawrence Great Lakes. J. Great Lakes Res. 4: 27-45.

_____. 1978b. Seasonal variations in densities of macrobenthic populations in the wave-zone of north central Lake Erie. J. Great Lakes Res. 4: 27-45.

_____. 1978c. Seasonal study of the fauna of bedrock substrates in the wave-zone of Lakes Huron and Erie. Can. J. Zool 56: 48-54.

Beak Consultants. 1978. Spatial biomass distribution and intake location, Consultant's biological studies package no. 3, once through cooling program. A report for Ontario Hydro November 1978 Processed.

Beak Consultants. 1979. Thermal discharge effects on the ecology of the macroinvertebrate propulsations of the littoral zone. A report for Ontario Hydro: No pagination.

Christie, W.J. 1973. A review of the changes in the fish species composition of Lake Ontario. Great Lakes Fishery Commission Tech. Rept. 23: 65 pp.

Coakley, J.P. and H.K. Cho. 1973. Beach stability investigations at Van Wagners beach, western Lake Ontario. Prod. 16th conf. Great Lakes Res. Inty. Assocn. for Great Lakes Research: 357-376.

- Denison, P.J. and F.C. Elder. 1970. Thermal inputs to the Great Lakes 1968-2000. Separate from Proc. 13th Confce. Great Lakes Research: 27 pp.
- Dunford, W.E. 1978. Whitefish spawning study. Ontario Hydro Research Division Rept. 78-48-k: 18 pp.
- Dunford, W.E. 1975. Aquatic Biological studies, Darlington G.S. - 1975. Ontario Hydro Research Division Rept. 75-367-H: 43 pp.
- Everest, G. 1972. Progress Report for April 1972 on studies of fish in thermal effluents. Ontario Hydro Generation Concepts. Divn.
- Frederick, L. 1977. Ecological life history of juvenile whitefish in northern Lake Michigan. Abstracts 20th Confce. on Great Lakes Research, Ann Arbor, Michigan. Int. Assocn. for Great Lakes Research: no pagination.
- Graham, J.J. 1956. Observations on the Alewife Pomolobus pseudoharengus (Wilson) in fresh water. Univ. Toronto Stud. Biol. Ser. 62, Pub. Ont. Fish Res. Lab. 74: 43 pp.
- Hoagman, W.J. 1973. The hatching, distribution, growth and food of the larval lake whitefish (Coregonus clupea formis Mitchill) of central Green Bay, Lake Michigan. Inst. Freshwater Res. Drottningholm (Sweden, Rept. 53: 20 pp.
- Hoagman, W.J. 1974. Vital activity parameters as related to the early life history of larvae and post-larvae lake whitefish. In J-H-F Blaxter (ed.). The Early Life History of Fish. Springer, N.Y.: 547-558.

- Kolenosky, D.P. and T.M. Joliff. 1979. Salmonid stocking completed in Canadian and U.S. waters of Lake Ontario in 1978 and projected for 1979. Minutes, Lake Ontario Committee, Great Lakes Fishery Comm. Mar. 13-14, 1979: 9 pp.
- Maher, J.F.B. 1978. Prediction of thermal discharge effects on whitefish, Darlington G.S. Ontario Hydro, Design and Development Divn. Rept. 78053: 63 pp.
- Minor, J.D. 1978. The avoidance response of white bass Morone chrysops to intermittent chlorination at the R.L. Hearn G.S. Ontario Hydro Research Divn. Rept. 78-203K: 18 pp.
- Minor, J.D. 1979. Progress Report: Pickering fish behaviour (July-December 1978) Ontario Hydro Research Divn. Rept. C79-3-K: 14 pp.
- Ontario Ministry of Natural Resources. 1978. Lake Ontario Fisheries Background Report. Lake Ontario Fisheries Tactical Planning Committee. Draft Aug. 1978: 81 pp.
- Quinn, T., G.W. Esch, T.C. Haxen and J.W. Gibbons. 1978. Long range movement and homing by largemouth bass (Micropterus salmoides) in a thermally altered reservoir. Copeia: 542-545.
- Sato, G.K. and C.H. Mortimer. 1975. Lake currents and temperatures near the western shore of Lake Michigan. Special Rept. 22: Center for Great Lakes Studies Univ. of Wisc. - Milwaukee.
- Spigarelli, S.A. and M.M. Thommes. 1976. Sport fishing at a thermal discharge into Lake Michigan. J. Great Lakes Res. 2: 99-110.

Utility Water Act Group. 1978. Thermal discharge Reports submitted to the United States Environmental Protection Agency. Biological effects of once-through cooling. Vol. 5. Great Lakes Basin and Connecting Water Bodies. Ch. 7. Summary of findings and conclusions: 39 pp.

Vascotto, G.L. 1978. Darlington "B" data report July - October 1978. Ontario Hydro Research Divn. Rept. 78-611-K: 2 vols.

Yaguchi, E.M. 1977. Nutrients and productivity as indicators of thermal effluent-upwelling interactions in Lake Michigan. J. Great Lakes Res: 57-64.

APPENDIX

Fisheries statistics with special reference to the Darlington area.

Notes:Tables 1 and 5

These cover the period when the commercial catch statistics were gathered on a county basis. These data were supplied from the original records of the Ministry of Natural Resources.

Table 2

Commercial statistics from 1956 have been segregated by statistical districts. In this revision, the waters off Ontario and Durham counties were combined in Statistical District 2. As Tables 1 and 5 show, there were substantial differences between the landings off these two counties. While the landings of the individual species have not been separated, there is information for the years 1965 through 1975 where the port of landing has been specified for the total catches. These data were made available by the Ministry and are presented in Table 4. There is a minor discrepancy in these statistics in that with respect to Port Hope, close to the eastern bounday of District 2, there are some catches landed from District 3. On that account, if the site of the catch has not been specified all information was deleted when the port records were compiled. This difficulty caused a major discrepancy between the catch as reported by district and as by port in 1970 and 1971. Otherwise, the concordance is excellent and there is no doubt that in recent years the catch reported for Statistical District 2 has been taken overwhelmingly off Durham County.

Table 3

The gillnets used to take these catches varied somewhat with the different sources. Sources (1) and (4) used stretched mesh sizes from 1-1/2" through 5" by half-inch intervals. Source (2) used stretched mesh sizes 1" through 2-1/2" by half-inch intervals then 3" through 5" at one-inch intervals. Source (3) used 2-1/2" through 5" mesh at half-inch intervals. With some exception noted in source (3) the panels were 50 ft. long. With regard to selectivity the one-inch mesh would favour the capture of smelt while these experimental nets as a whole would favour the capture of small fish as opposed to the commercial catch.

TABLE 1

COMMERCIAL LANDINGS* FROM LAKE ONTARIO OFF DURHAM COUNTY
COURTESY, ONTARIO MINISTRY OF NATURAL RESOURCES

Year	Lake Herring	Lake Whitefish	Lake Trout	Pike	Smelt	Yellow Perch	Chubs (Coregenus)	Catfish (Bullhead)	Carp	Coarse Fish
1924	767	104,002	7,296							1,804
1925	5,425	62,875	6,925							2,700
1926	10,048	42,556	7,391			1,000				3,409
1927	74,891	19,460	5,340					368		2,600
1928	45,913	7,105	16,409						1,665	4,350
1929	87,579	10,371	5,750						825	6,854
1930	55,646	7,964							150	2,250
1931	72,809	10,647	450	450					150	448
1932	31,083	7,846	1,051						2,770	1,200
1933	188,771	12,499	380	50					561	2,886
1934	39,479	13,765	200							
1935	143,643	5,600	200							
1936	182,486	9,766								
1937	184,147	7,159	50						1,539	
1938	167,618	11,437	510							
1939	292,675	32,087								
1940	284,661	2,909								
1941	282,286	1,298								
1942	170,532	500								
1943	195,570	1,500								
1944	194,376	2,119		321		153			30	875
1945	143,787									
1946	70,187	2,028	78						943	
1947	136,457	433							255	2,623
1948	89,571	1,685								128
1949	60,984	694								
1950	67,877									
1951	33,346	538								387
1952		no record available								2,275
1953	12,743									
1954	3,811									
1955	-	250								

*All landings are given as pounds in Tables 1 through 5.

TABLE 2

COMMERCIAL LANDINGS FROM STATISTICAL DISTRICT 2, LAKE ONTARIO
FROM THE COMMERCIAL FISH SECTION, ONTARIO MINISTRY OF NATURAL RESOURCES

Notes: Add 29 lb. of Walleye in 1959. Suckers combined
with "Animal Food" under "Coarse Fish"

	Lake Herring	Lake Whitefish	Lake Trout	Pike	Smelt	Menominee	Yellow Perch	Catfish Bullhead	Carp	Eel	White Bass	Coarse Fish
1956	5,960	63	-	-	115,474	-	-	-	-	-	-	9,590
1957	-	-	-	-	45,076	-	-	-	-	-	-	1,870
1958	-	-	-	-	49,356	-	-	-	-	150	-	-
1959	-	55	19	-	61,569	-	-	-	-	630	-	970
1960	1,438	-	-	-	32,293	-	-	-	-	532	-	123
1961	4	-	-	-	47,881	-	-	-	-	-	-	96
1962	-	-	-	-	-	-	133	-	-	465	-	-
1963	-	-	-	-	61,640	-	170	4	15,119	189	-	162
1964	-	-	-	-	21,444	-	2	17	3,417	230	-	-
1965	-	-	-	-	43,601	-	94	-	-	-	-	-
1966	-	-	-	-	14,000	-	71	-	938	-	-	115
1967	-	41	-	-	50,628	-	90	11	989	43	53	58
1968	-	-	-	-	72,775	-	-	-	-	-	-	53
1969	-	-	-	-	17,470	-	-	-	-	-	-	-
1970	-	23	-	19	5,390	-	780	26	-	-	-	16
1971	-	-	-	33	32,952	-	57	3	29	190	15	31
1972	-	46	-	42	30,266	-	-	-	-	-	-	13
1973	-	21	-	-	12,990	-	-	-	93	100	-	28
1974	-	34	-	22	22,280	-	2,896	-	282	73	19	-
1975	2	-	-	178	18,002	-	438	-	50	101	20	3,737
1976	-	-	-	-	30,111	387	-	-	571	924	170	1,640
1977	-	-	-	-	4,606	180	-	-	-	-	6	242

TABLE 3

SUMMARY OF VARIOUS GILLNET CATCHES OF FISH
TAKEN OFF THE DARLINGTON SITE IN RECENT YEARS

Sources: (1) Dunford, 1975
(2) Beak Consultants, 1978
(3) Dunford, 1978
(4) Vascotto, 1978

Species	1975		1976		1977		1978
	May-July	Oct.	May	July	April-May	Nov-Dec	May-Oct
Alewife	26	169	1439	2283	323	115	5348
Gizzard Shad			1			18	17
Coho		4		1		1	20
Splake						13	16
Menominee		3	1	1	2	293	9
Smelt	1	101	194	123	1029	10	888
Lake Chub		13		1	5		11
Spot Tail		5					24
Common Sucker	72	26		1	8	222	175
Bullhead	42					10	22
White Perch	4	1				11	2
White Bass	2	3				36	3
Yellow Perch	10	2				6	69
Source	(1)	(2)	(2)	(2)	(2)	(3)	(4)

Also taken over whole period: Rainbow Trout 4; Brown Trout 5; Lake Whitefish 5;
Carp 8; Northern Sucker 2; Trout Perch 1; Drum 2;
Smallmouth Bass 1.

TABLE 4

WEIGHTS OF FISH LANDED AT THE PORTS INDICATED

DATA COURTESY COMMERCIAL FISH BRANCH,
ONTARIO MINISTRY OF NATURAL RESOURCES

<u>Year</u>	<u>Whitby and Oshawa</u>	<u>Bowmanville and Port Hope</u>
1965	398	42,044
1966	1,401	13,937
1967	289	51,637
1968	255	72,520
1969	610	16,860
1970	112	1,009
1971	371	14,637
1972	507	29,860
1973	142	13,090
1974	617	15,381
1975		23,287
1976		33,881

TABLE 5

COMMERCIAL LANDINGS FROM LAKE ONTARIO OFF ONTARIO COUNTY
COURTESY, ONTARIO MINISTRY OF NATURAL RESOURCES

Notes: Smelt not recorded until 1953; 90 pounds blue pike recorded, 1943;
1953 pounds chubs recorded, 1953; 5 pounds walleye recorded, 1954

	Lake Herring	Lake Whitefish	Lake Trout	Pike	Smelt	Menominee	Yellow Perch	Catfish Bullhead	Carp	Coarse Fish
1924		87,704	2,719							2,817
1925	2,443	73,321	3,057							3,000
1926		71,726	2,802				300			7,190
1927	4,845	34,701	1,204							1,814
1928	7,127	13,996								439
1929	8,524	15,331	744							800
1930	12,896	7,801	20					25		
1931	500	5,692								
1932	600	2,285	2,576				100			
1933		6,249	50							1,347
1934	2,796	19,188	292				187			577
1935	3,253	20,650	43	212			275	126	6,038	8,788
1936	1,757	25,979	980	17			254	50	8,000	397
1937	6,398	13,074	365	118			224	100	2,000	645
1938	15,404	15,184	2,275	97			2,345			196
1939	13,136	11,234	552	479			1,083	23	2,550	842
1940	11,684	5,949	66				324			654
1941	6,845	7,160	66	51			374	94	576	287
1942	5,849	3,309	24				572		947	5,845
1943		no record available								
1944	4,053	3,108	20				301		38	2,720
1945	22,340	2,955					115			160
1946	4,704	1,392					115			
1947	3,586	4,294					2,660			
1948	1,865	4,761								
1949	19,868	1,483							470	202
1950	26,948	2,529								67
1951	5,726	918								349
1952		no record available								
1953	252	1,706			20					
1954	1,065	861		14	1,017					
1955	145	453			2,232					
						62				50
						238	4			
						215				

TABLE 6

Numbers of menominee taken per set rounded to the nearest whole number.
From Table 3, Dunford 1978 (78-48-K).

<u>Date</u>	<u>DP</u>	<u>TV</u>	<u>RHW</u>	<u>RH</u>	<u>RHE</u>	<u>PD</u>	<u>BH</u>
Nov. 10-12	2	X	1	1	3	11	12
Nov. 13-16	0	1	1	1	28	7	X
Nov. 23-25	2	X	10	8	4	2	1
Nov. 30 - Dec. 6	2	4	13	10	6	0	X

- DP - Darlington Park - 7 km w. of Raby Head
- TV - Twin Valleys - 1 km w. of discharge
- RHW - Raby Head West - near proposed discharge
- RH - Raby Head - central on site
- RHE - Raby Head East - 0.8 km e. of Raby Head
- PD - Port Darlington - 5 km e. of Raby Head
- BH - Bond Head - 14 km e. of Raby Head

TABLE 7

A SUMMARY OF RECENT LAKE ONTARIO CREEK CENSUS REPORTS

From Table 4, Ontario Ministry of Natural Resources
1978 Draft, Lake Ontario Fisheries Background Report

<u>Location</u>	<u>Season Monitored</u>	<u>Effort ¹ (angler-days)</u>	<u>Yield (no. of fish)</u>	<u>Hours Per Game Fish</u>
1. Wolfe Is. Howe Is.	summer '77	20,900	56,900 sm. bass 44% y. perch 39% n. pike 14%	2.5
2. Bay of Quinte	summer '76	16,000	9,400 sm. bass 41% walleye 37%	6.9
3. East, West Consecon Lakes	winter '78	1,700	700 walleye 64% n. pike 36%	9.6
4. Ganaraska R. at Port Hope	fall '76	3,100	900 rainbow tr. 93%	17.0
	spring '77	7,100	1,000 rainbow tr. 100%	32.0
5. Wilmot Crk.	fall '76	1,500	400 rainbow tr. 95%	16.6
6. Duffin Crk. Estuary	summer '75	1,600	bullhead	3.3
7. Frenchman Bay	summer '75	5,400	bullhead rock bass	3.0
8. Rouge R. Estuary	summer '75	8,800	y. perch bullhead	3.8
9. Hearn G.S.	summer '75	8,300	white bass	3.0
10. Humber R.	summer '75	1,200	panfish bullhead carp	1.8
11. Etobicoke Crk. Estuary	summer '75	1,600	bullhead	7.7
12. Credit R. ² Bronte Ck. mouths	early fall '77	29,700	9,100 coho salmon 93%	20.0
	Total	<u>106,900</u>		

¹ angler day = angler hours/4

² does not include angling from shore

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James F. MacLaren Ltd.

REPORT TO ONTARIO HYDRO ON ASSESSMENT OF THE
SHORELINE DISCHARGE ALONG THE EXPOSED SHORE OF
LAKES 1979.

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